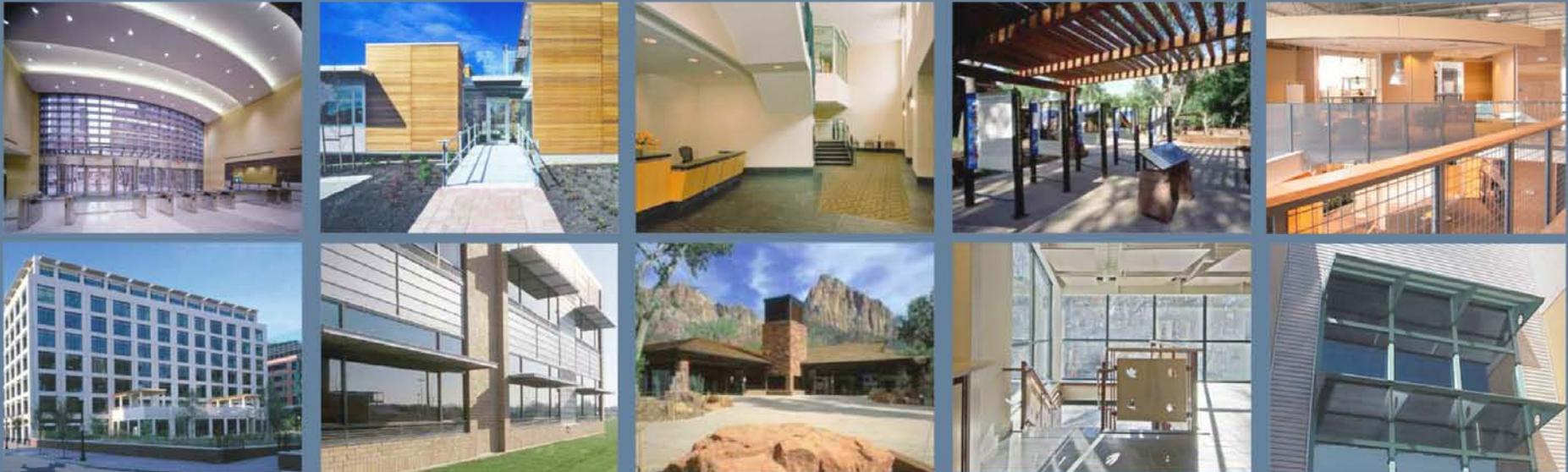


# EnergyPlus: DOE's Next Generation Simulation Program



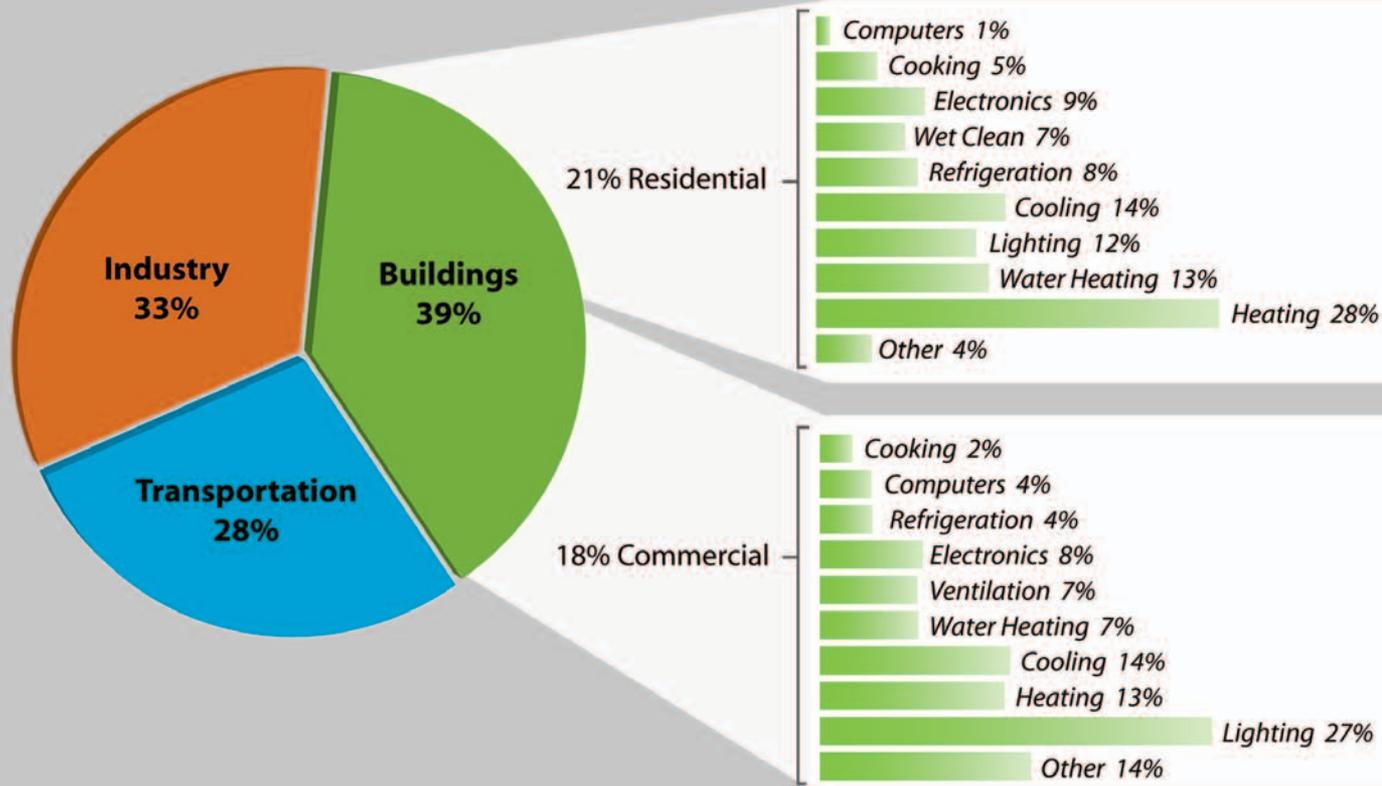
**Building Technologies Program**

February 16, 2010

**Drury B. Crawley, Ph.D.**

U.S. Department of Energy  
Energy Efficiency and Renewable Energy

## 2006 Buildings Share of U.S. Primary Energy Consumption End-Uses



Source: Buildings Energy Data Book <http://buildingsdatabook.eren.doe.gov/>  
Tables 1.1.3, 2.1.5, 3.1.4

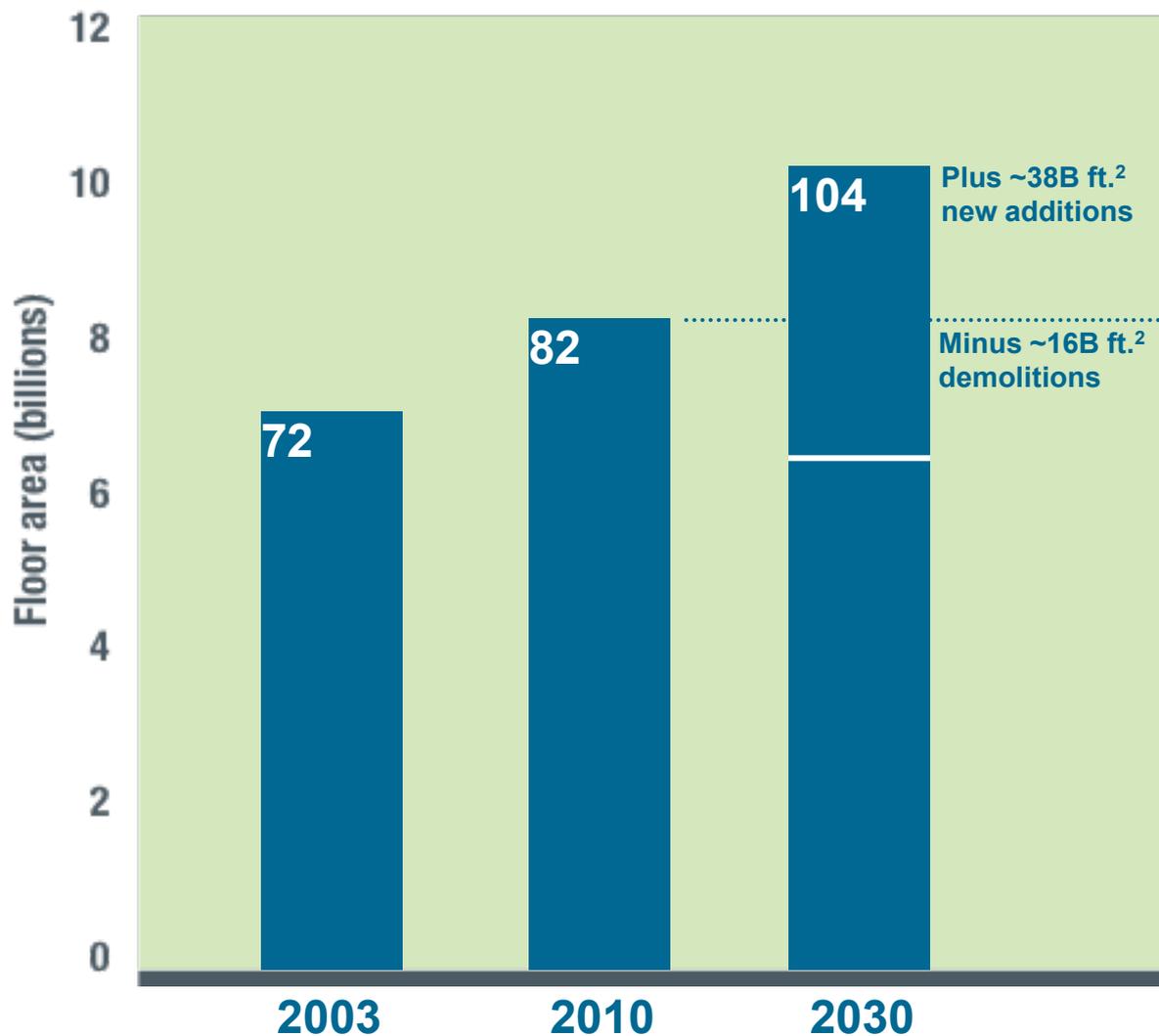
Note: The "Adjust to SEDS" percentages for the residential and commercial end-use splits were distributed among the other categories.

Commercial buildings account for:

- 18% of U.S. energy
- 18% of greenhouse gas emissions (~1,000 MMT of CO<sub>2</sub>e)
- slightly less than India's entire energy consumption and GHG emissions

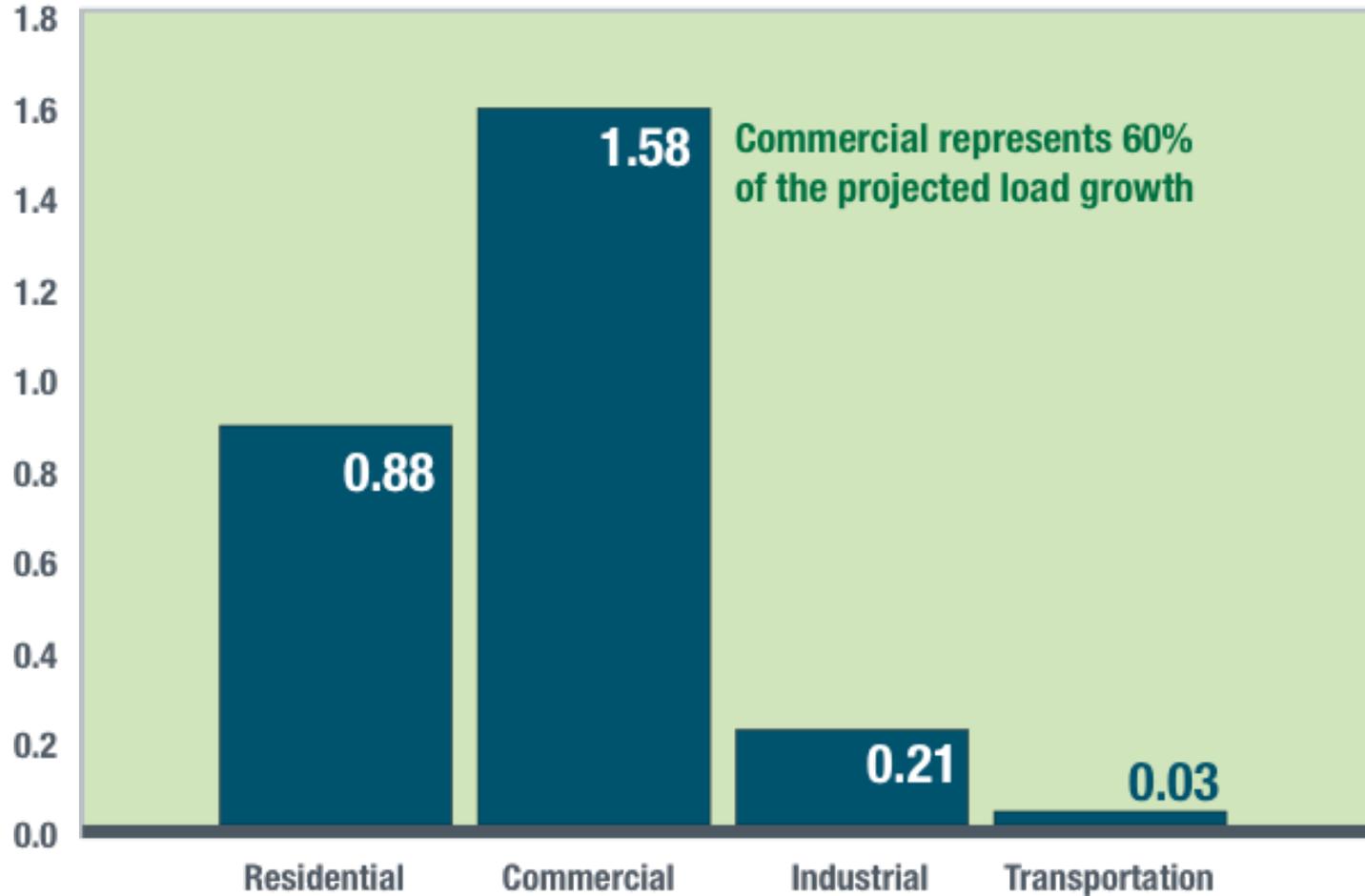


# Commercial Square Footage Projections



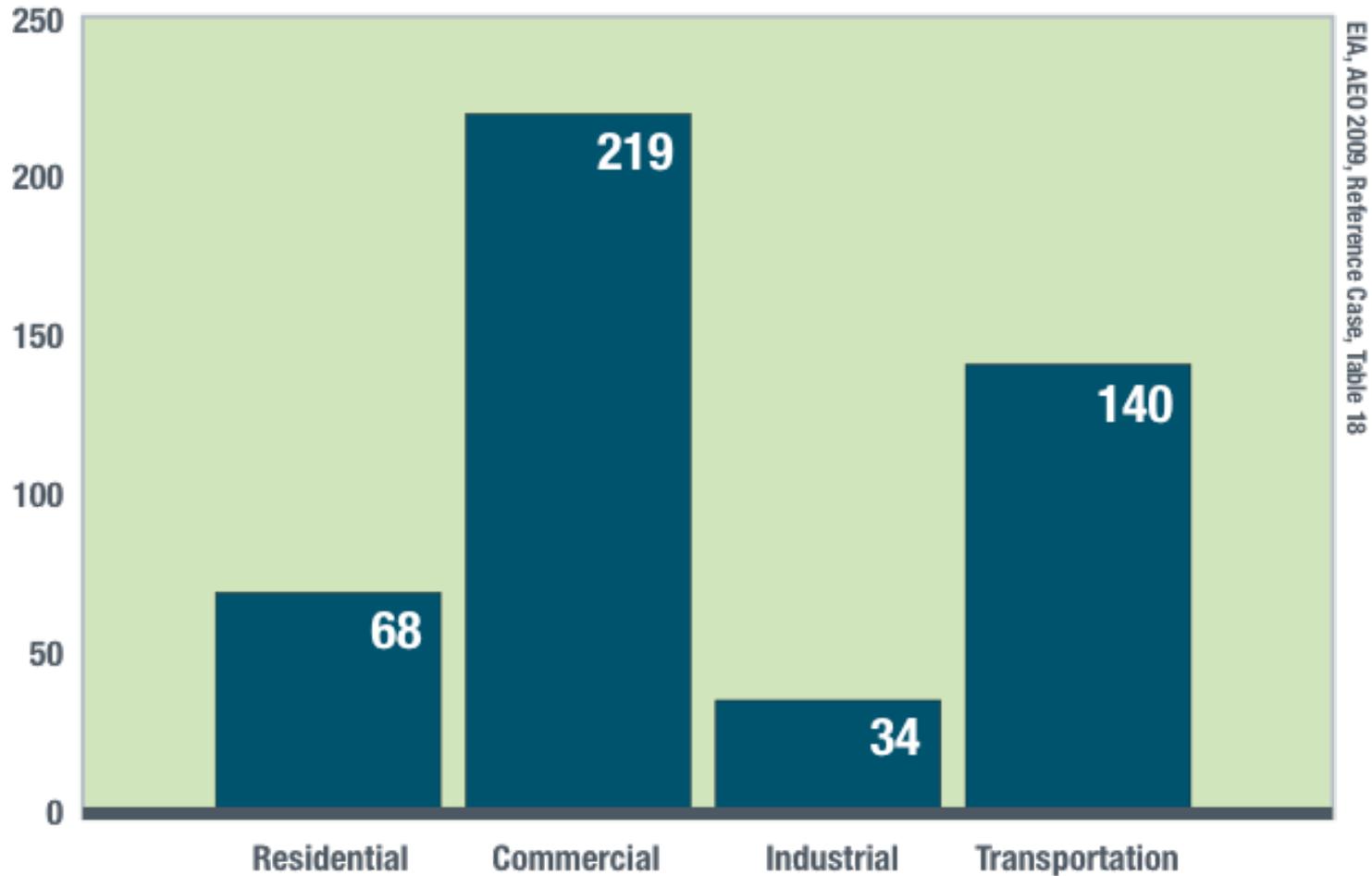
Source: EIA's Annual Energy Outlook 2009, Table 5.

## 2010 to 2030, by End-Use Sector (*site quad*)



# Projected Increase in Carbon Dioxide Emissions

## 2008 to 2030, by End-Use Sector (MMTCO<sub>2</sub>-e)



# Goals for Commercial Buildings



**2050**

All commercial buildings  
are ZEB (EISA 2007)  
83% reduction in U.S. GHGs  
by 2050 (Obama)

**2040**

50% of commercial  
building stock is ZEB  
(EISA 2007)

**2039**

All New are ZEB (EISA 2007)  
Stock energy performance  
50% better w.r.t. CBECS 2003  
(CBI Performance Goal)

**2025**

Improve New 70% with  
5-year payback or less  
(CBI Performance Goal)

**2020**

17% reduction in  
GHGs rel. to 2005  
(Senate Proposal)

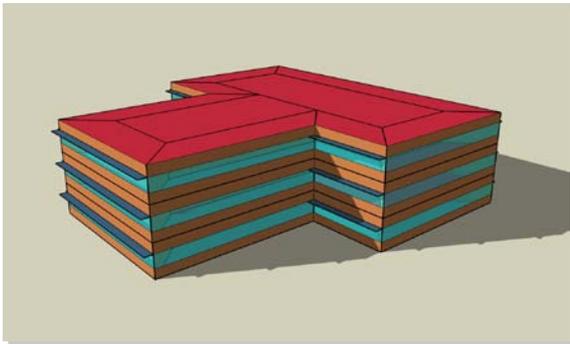
**2015**

Improve New 50%  
(CBI Performance Goal)





- Fully integrated building, envelope, HVAC, water, and renewables simulation program
- Available free at [www.energyplus.gov](http://www.energyplus.gov)
- Originally based on BLAST and DOE-2.1E, far exceeds their capabilities now



- One of the most robust simulation tools available in the world today
- Enables integrated energy performance analysis of low-energy technologies in commercial and residential buildings including on-site generation and renewable energy sources
- Interfaces available from private sector developers as well as Web interface
- Version 1.0 Launched April 2001; twice yearly updates
- 100,000 copies downloaded to date
- Windows XP/Vista/7, Linux & Mac

- Designed for flexibility and expansion
- Many new low-energy technologies
- Sub-hourly calculations
- Many output metrics: energy, water, emissions
- 3,800 pages of documentation and testing/validation reports
- Weather data for more than 2,100 locations worldwide (Google Earth layer for weather data)



[buildings.energy.gov/energyplus/download/  
energyplusweatherdata.kmz](https://buildings.energy.gov/energyplus/download/energyplusweatherdata.kmz)



## Freedom Tower

- Building energy simulation of alternatives
- Aggressive energy and environmental goals
- Code compliance

## New York Times

- Building energy simulation of alternatives
- Controls, peak demand, energy use impacts





## San Francisco Federal Building

- Natural cross-ventilation system
- No mechanical cooling in high-rise portion
- Building management controls

## San Diego Supercomputer Center

- Thermal simulation
- Natural displacement ventilation analysis
- Climate analysis



**“Every building is a forecast.  
Every forecast is wrong.”**

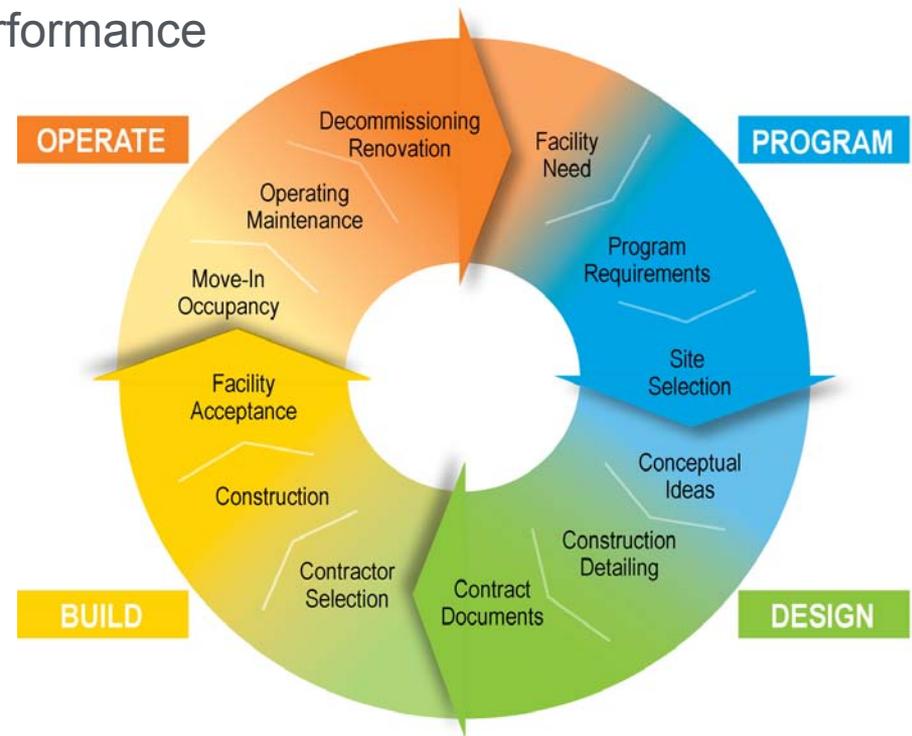
***Stewart Brand***

- In DOE's low-energy building research, simulation has been critical for designing and operating buildings to support decision-making
- BUT, compared to simulations, real buildings
  - use more energy
  - produce less power
  - have worse controls
  - have more occupant complaints
  - GIGO



# Why Use Energy Simulation?

- Inform energy decisions from earliest phases of design through construction and into operation
- Help the design team and owner focus energy-use reduction efforts where they will be most effective
- Permit assessment of predicted performance with established benchmarks or project goals
- Size renewable energy systems and determine their likely % contribution
- Evaluate alternatives through programming, design, construction, operation—retrofit, too
- Simulation is cheaper than constructing the wrong building!







- Simultaneous simulation of loads, systems, and plant
- Air and water loops solved iteratively each time-step
- Provides tighter coupling between the air- and water-sides of the system and plant
- Allows capacity limits to be modeled more realistically
- Loads “not met” result in zone temperature and humidity changes
- Time-dependent conduction
  - conduction through building surfaces calculated with conduction transfer functions
  - heat storage and time lags
  - finite difference, with variable properties to model phase-change materials

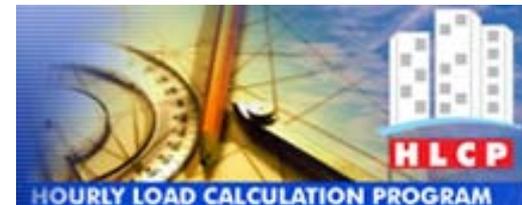
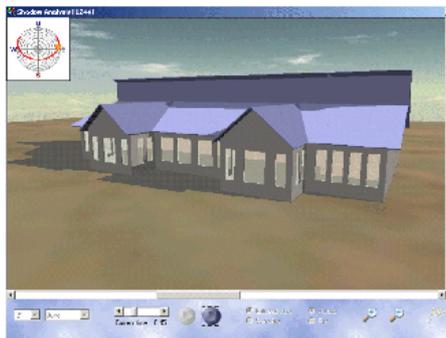
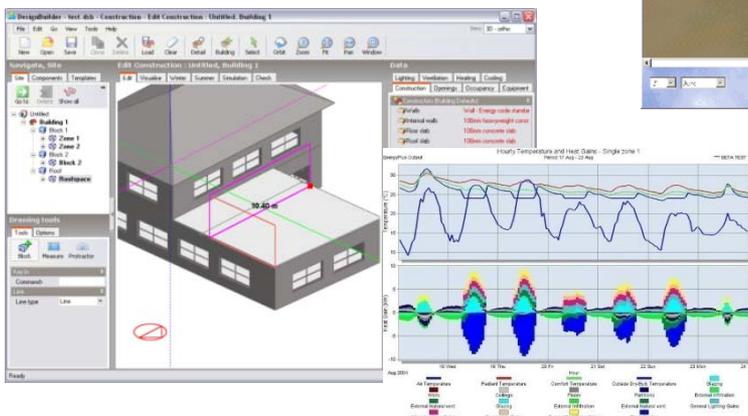


- Released October 2009
- New features include
  - EnergyManagementSystem implemented, including EnergyPlus runtime language with numerous actuators. A separate application guide covers its use.
  - large horizontal openings added to AirflowNetwork for natural ventilation
  - plant and condenser HVAC loops merged with significant improvements throughout
  - walk-in refrigeration, refrigeration cascade condenser, and refrigeration secondary loop
  - evaporative fluid cooler

# Private Sector User Interfaces



PV modeling by EnergyPlus



ECOTECT



EFEN

Easy Energyplus  
(Chinese)

COMFEN

EnergyGauge

TREAT Plus

ESP-r

EPlusInterface

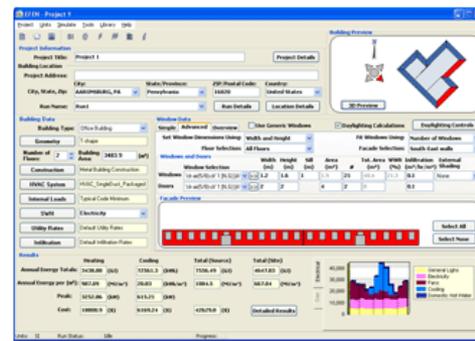
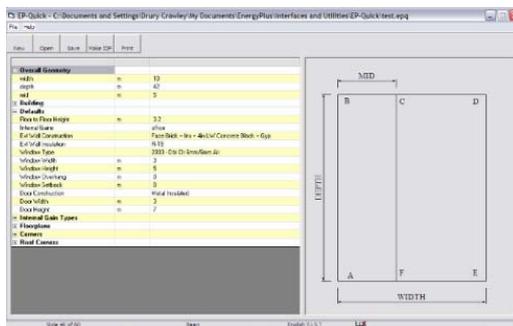
HVAC Energy

SolarShoeBox

xEsView

others....

EP-Quick





- Translate CADD to EnergyPlus
  - International Alliance for Interoperability
    - any CADD software that supports interoperability
    - available since 2001
    - limited to what CADD tools export—typically only geometry
  - Green Building Studio (now part of AutoDesk)
    - Web-based conversion of major CADD formats to energy simulation inputs
    - limited coverage
    - requires users to create their CADD drawings in structured way (may not follow designer regular methods)
- Direct from CADD to EnergyPlus
  - Graphisoft adding direct export from ArchiCAD to EnergyPlus
  - Bentley recently purchased HEVACOMP and investigating direct link from Microstation
- Interoperability is key to getting energy simulation mainstream. Other drivers—zero-energy buildings and green building rating systems



- Google SketchUp 3-D environment

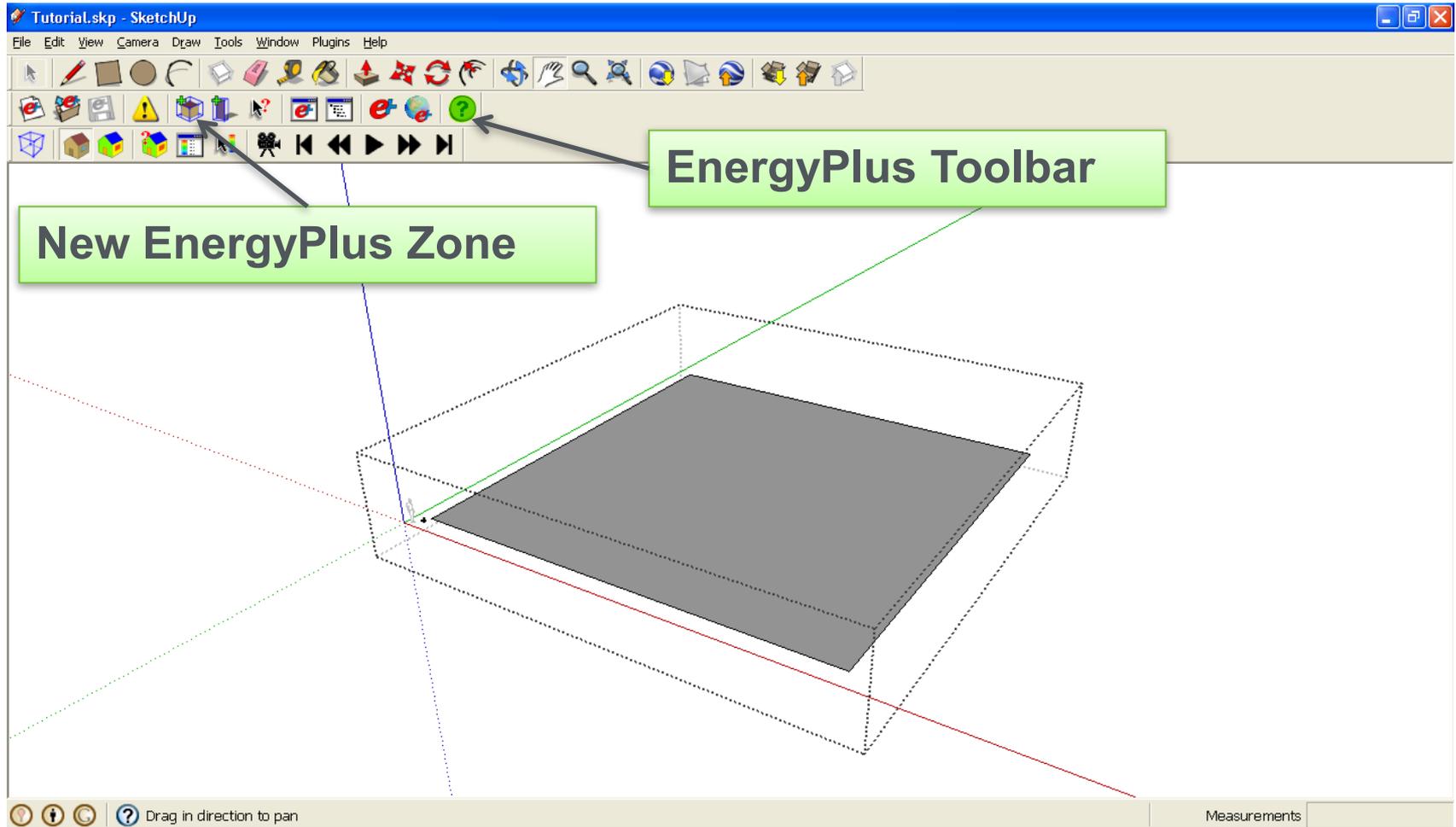
- intuitive, easy-to-use 3-D drawing software available from Google
- popular with architects
- powerful API using Ruby programming language

- OpenStudio

- adds EnergyPlus functionality to Google SketchUp (Free and Pro versions)
- available free at [www.energyplus.gov](http://www.energyplus.gov)
- distributed under open source license (GPL)
- provide feedback during the conceptual phase of the design process
- geometry only—must have energy model in mind

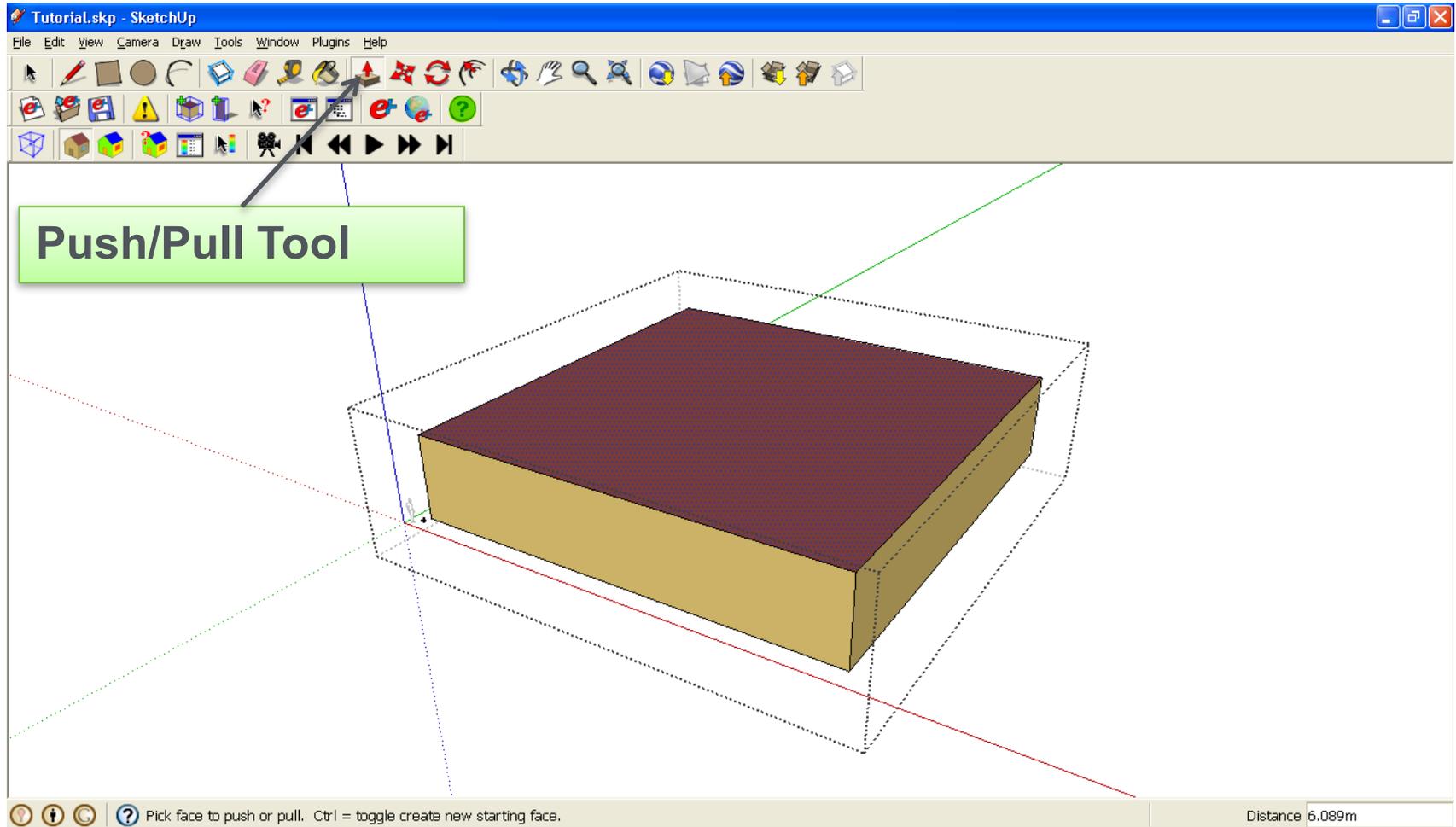


# Create Geometry from Scratch

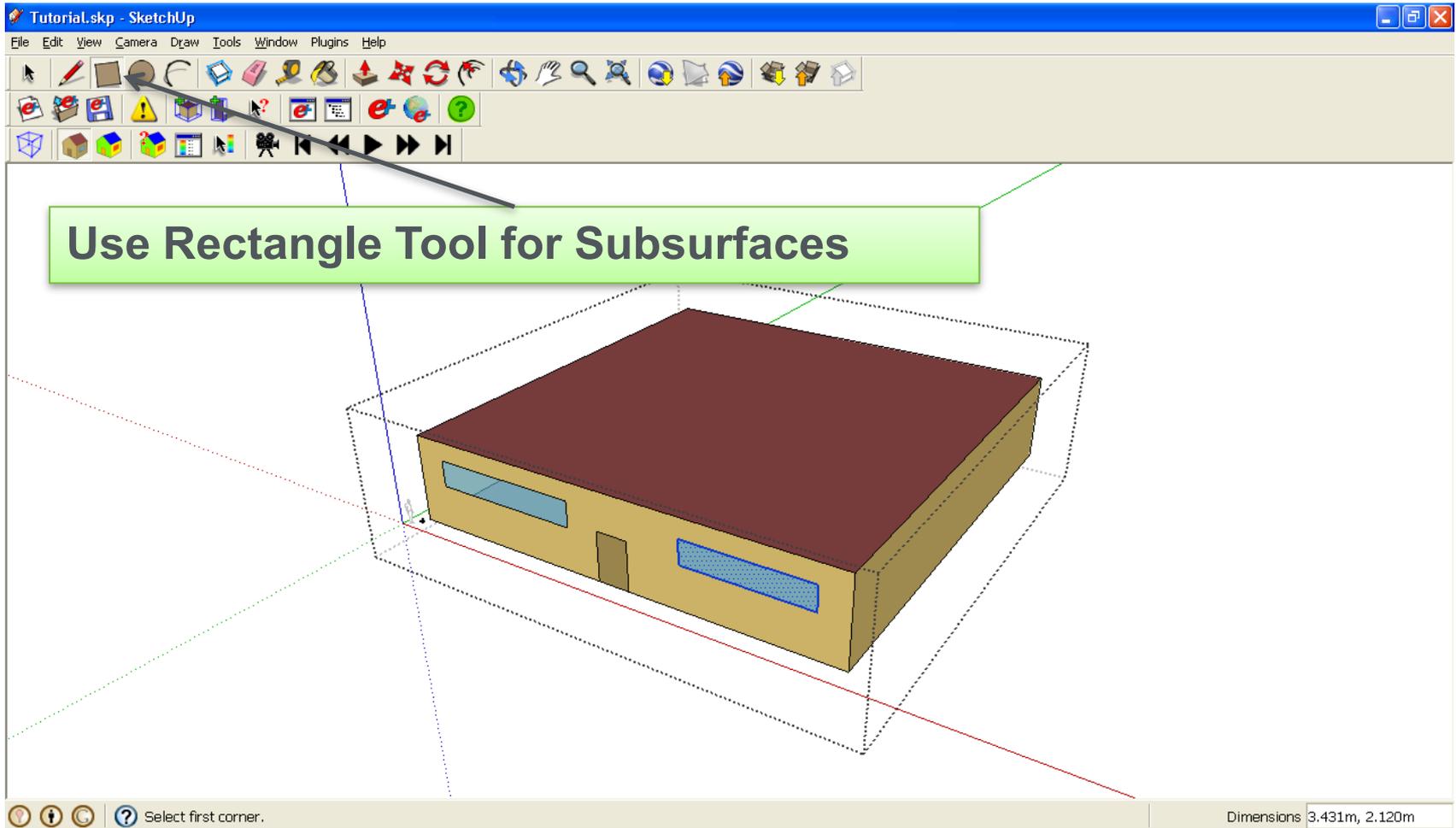


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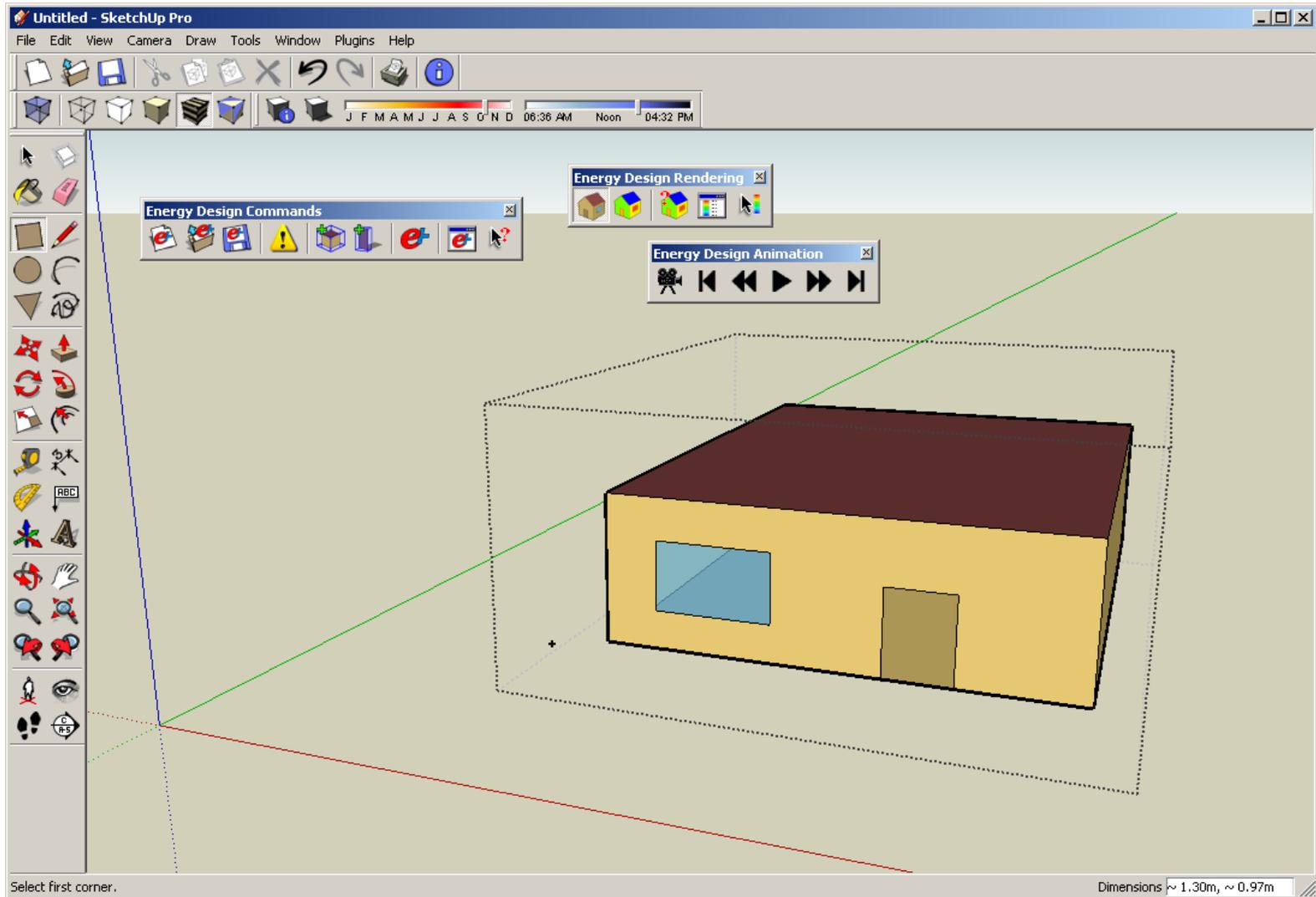
# Create Geometry from Scratch



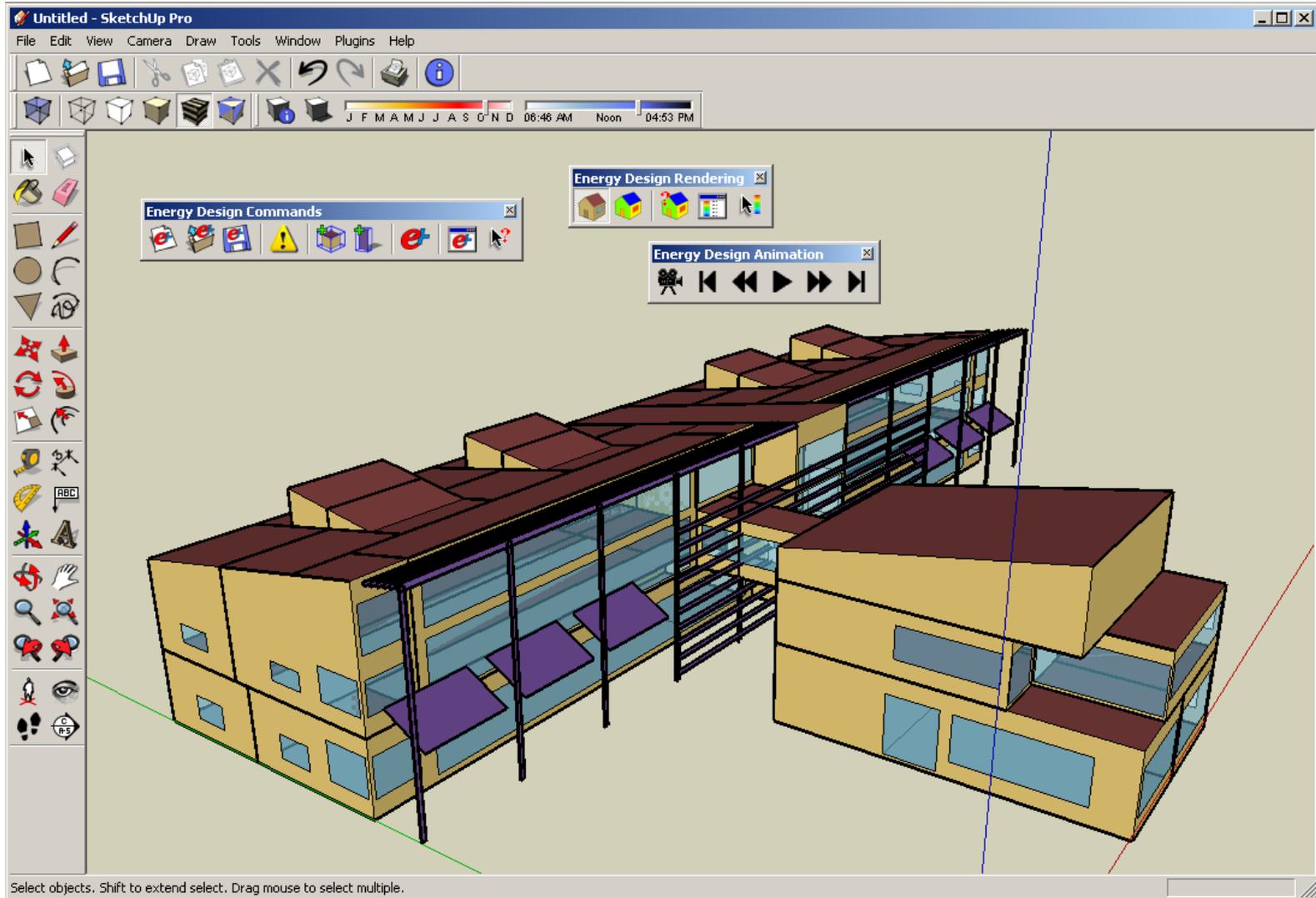
Introduction to EnergyPlus—Part 1. Copyright 2002–2009 U.S. DOE



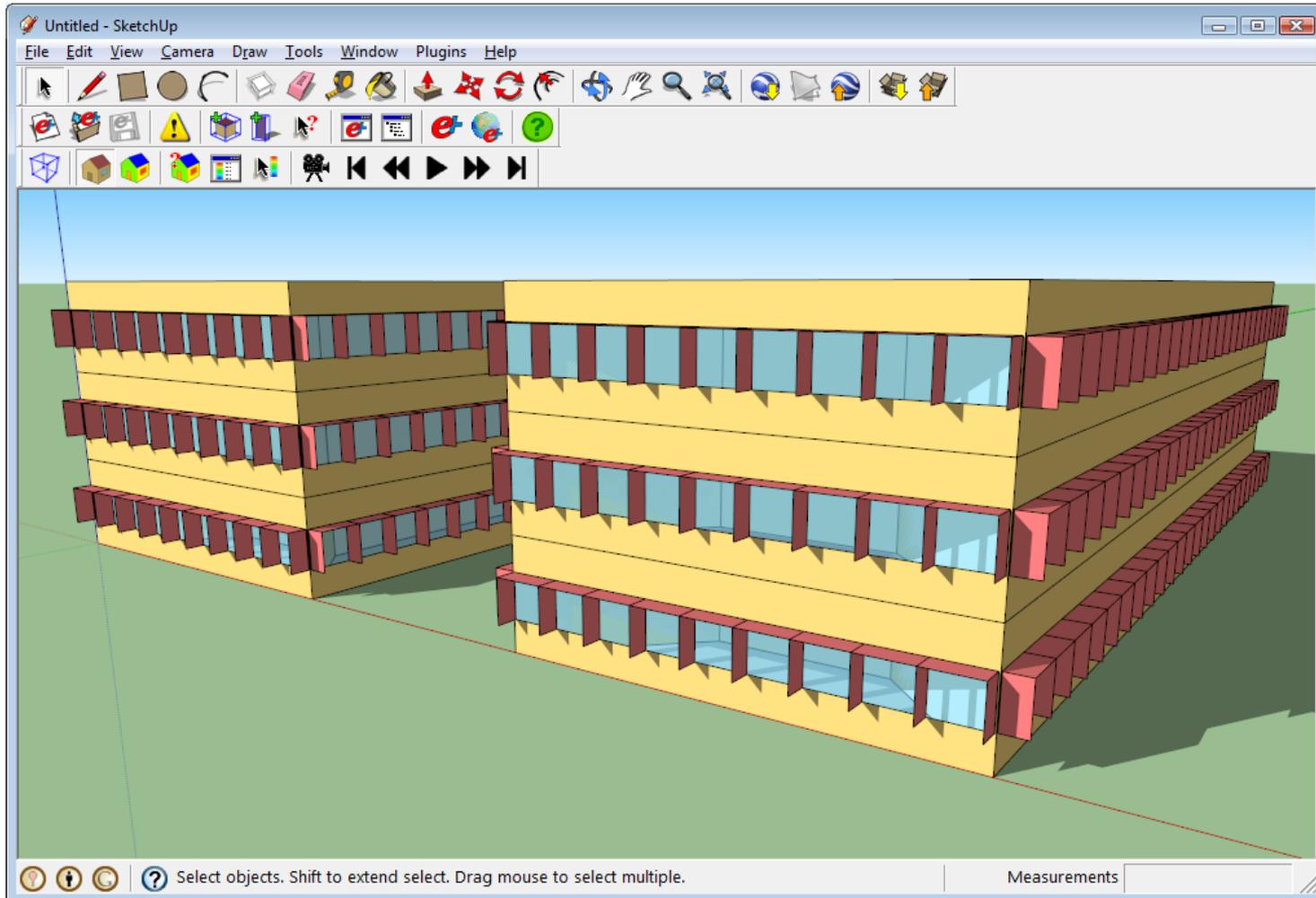
# Create Geometry from Scratch



# Open an Existing Input File



# Open/Edit an Input File



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# Edit Zone Properties

The screenshot shows the SketchUp Pro interface with a 3D model of a building. A specific zone is highlighted with a blue wireframe. The 'Object Info' panel on the right provides the following data:

Object Inputs	
Class:	<b>ZONE</b>
Name:	ZN_1_FLR_3_SEC_3
Rotation:	0.0000 (deg)
Multiplier:	1.0000
<input checked="" type="checkbox"/> Include In Total Building Floor Area	

Object Summary	
Surfaces: 8	Sub Surfaces: 47
Unit Floor Area: 600.0 (m <sup>2</sup> )	Total Floor Area: 600.0 (m <sup>2</sup> )
Total Exterior Surface Area: 942.0 (m <sup>2</sup> )	Percent Exterior Glazing: 16.4 %

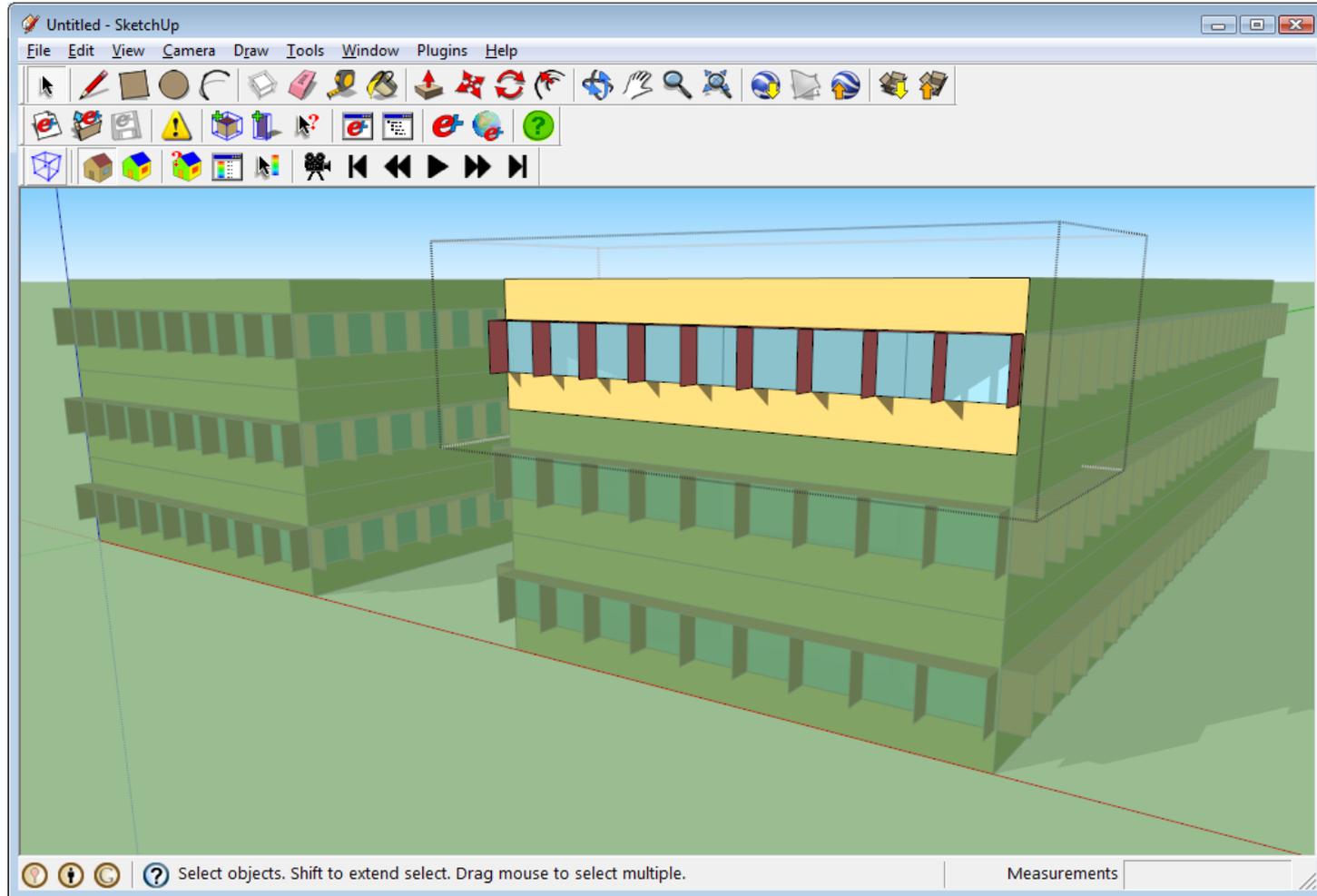
  

**Object Text**

```
ZONE,  
ZN_1_FLR_3_SEC_3, I- Zone Name  
0.0000, I- Relative North  
25.0000, I- X Origin  
0.0000, I- Y Origin  
7.6000, I- Z Origin  
1, I- Type  
1.0000, I- Multiplier  
3.8000, I- Ceiling Height  
2280.0000, I- Volume  
, I- Zone Inside Convection Algorithm  
,  
YES; I- Include in Area
```

Select objects. Shift to extend select. Drag mouse to select multiple.

# Edit a Zone



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# Edit Surface Properties

Object Info

Object Inputs

Class: SURFACE:HEATTRANSFER

Name: Bedroom4 R-1

Type: Roof

Construction: Roof

Zone: Bedroom4

Outside Boundary Condition: Exterior Environment

Sun Exposed  Wind Exposed

View Factor To Ground: 0

Outside Boundary Object:

Object Summary

Vertices: 4 Sub Surfaces: 0 Percent Glazing: 0.0 %

Gross Area: 22.79 (m<sup>2</sup>) Net Area: 22.79 (m<sup>2</sup>)

Object Text

```
SURFACE:HEATTRANSFER,  
Bedroom4 R-1, !- User Supplied Surface Name  
ROOF, !- Surface Type  
Roof, !- Construction Name of the Surface  
Bedroom4, !- InsideFaceEnvironment  
ExteriorEnvironment, !- OutsideFaceEnvironment  
, !- OutsideFaceEnvironment Object  
SunExposed, !- Sun Exposure  
WindExposed, !- Wind Exposure  
0, !- View Factor to Ground  
4, !- Number of Surface Vertex Groups -- Number of (  
9.093200, !- Vertex 1 X-coordinate {m}  
4.673600, !- Vertex 1 Y-coordinate {m}  
2.286000, !- Vertex 1 Z-coordinate {m}  
9.093200, !- Vertex 2 X-coordinate {m}
```

Select objects. Shift to extend select. Drag mouse to select multiple.

# Run Simulation

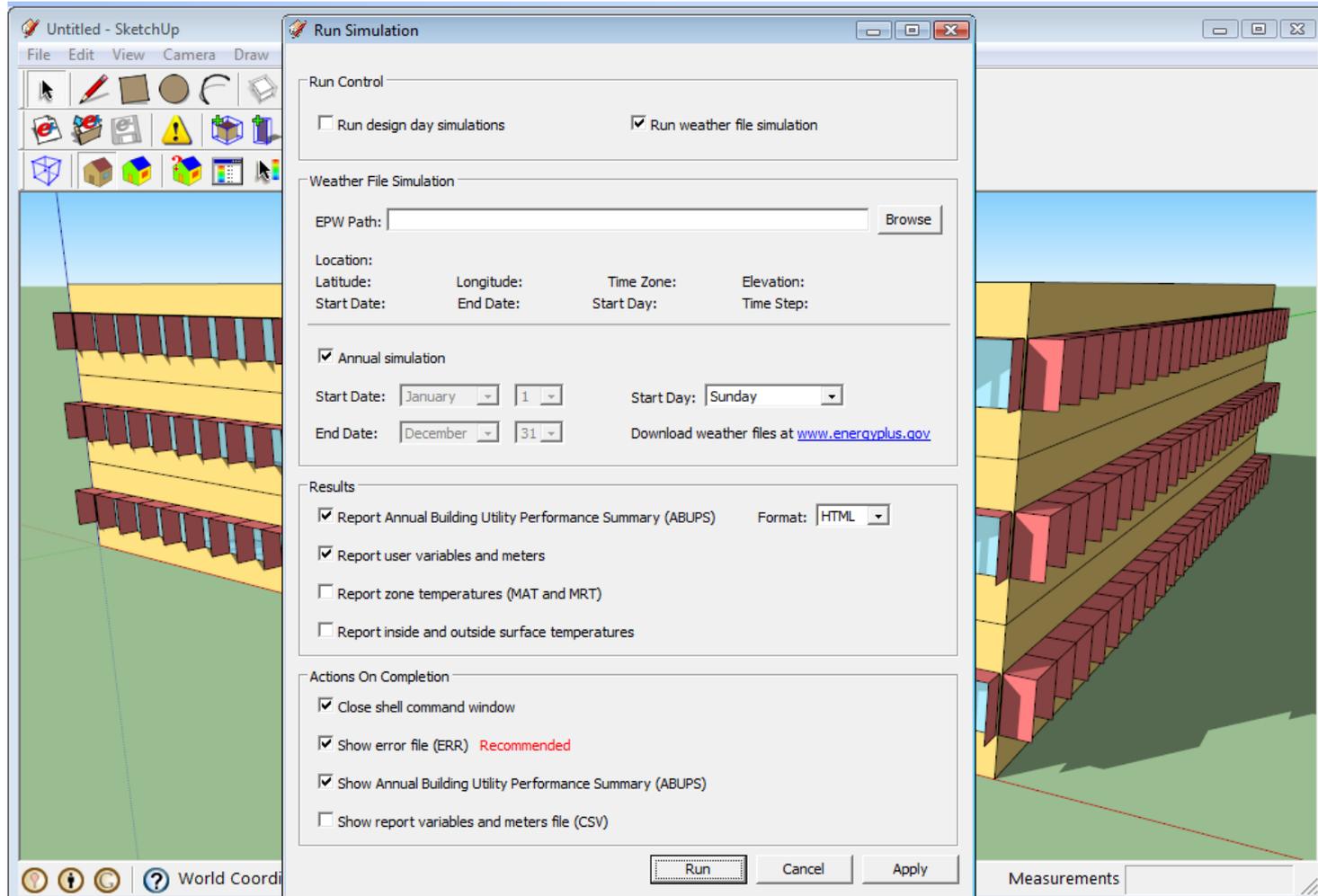
The screenshot displays the SketchUp Pro interface with the 'Run Simulation' dialog box open. The dialog box has two checked options: 'Run design day simulations' and 'Run weather file simulation'. The 'Weather File Simulation' section shows the EPW Path as 'C:/Program Files/Google/SketchUp 6/Plugins/EnergyDesignPlugin/...', Location as 'San Jose Intl AP, CA, USA', and simulation parameters: Latitude: 37.37, Longitude: -121.93, Time Zone: -8.0, Elevation: 16.0 m, Start Date: 1/1, End Date: 12/31, Start Day: Sunday, and Time Step: 60 min.

Below the dialog box, the 'EnergyPlus - SurfaceTest.idf' output window is visible, showing the following text:

```
St Calculate Inside Surface Heat Balance
Er Calculate Air Heat Balance
Er Initializing HVAC
Re Reporting Surfaces
Re Warming up <2>
Re Warming up <3>
Re Warming up <4>
Re Starting Simulation at 12/21 for PHOENIX ANN HTG 99.6% CONDNS DB
Re Initializing New Environment Parameters
Re Warming up <1>
Re Warming up <2>
Re Warming up <3>
Re Warming up <4>
Re Starting Simulation at 07/21 for PHOENIX ANN CLG .4% CONDNS DB=>MWB
Re Initializing New Environment Parameters
Re Warming up <1>
Re Warming up <2>
Re Warming up <3>
Re Warming up <4>
Re Starting Simulation at 01/01 for San Jose Intl AP CA USA TMY3 WMO#=724945
Re Updating Shadowing Calculations, Start Date=01/21
Re Continuing Simulation at 01/21 for San Jose Intl AP CA USA TMY3 WMO#=724945
Re Updating Shadowing Calculations, Start Date=02/10
Re Continuing Simulation at 02/10 for San Jose Intl AP CA USA TMY3 WMO#=724945
```

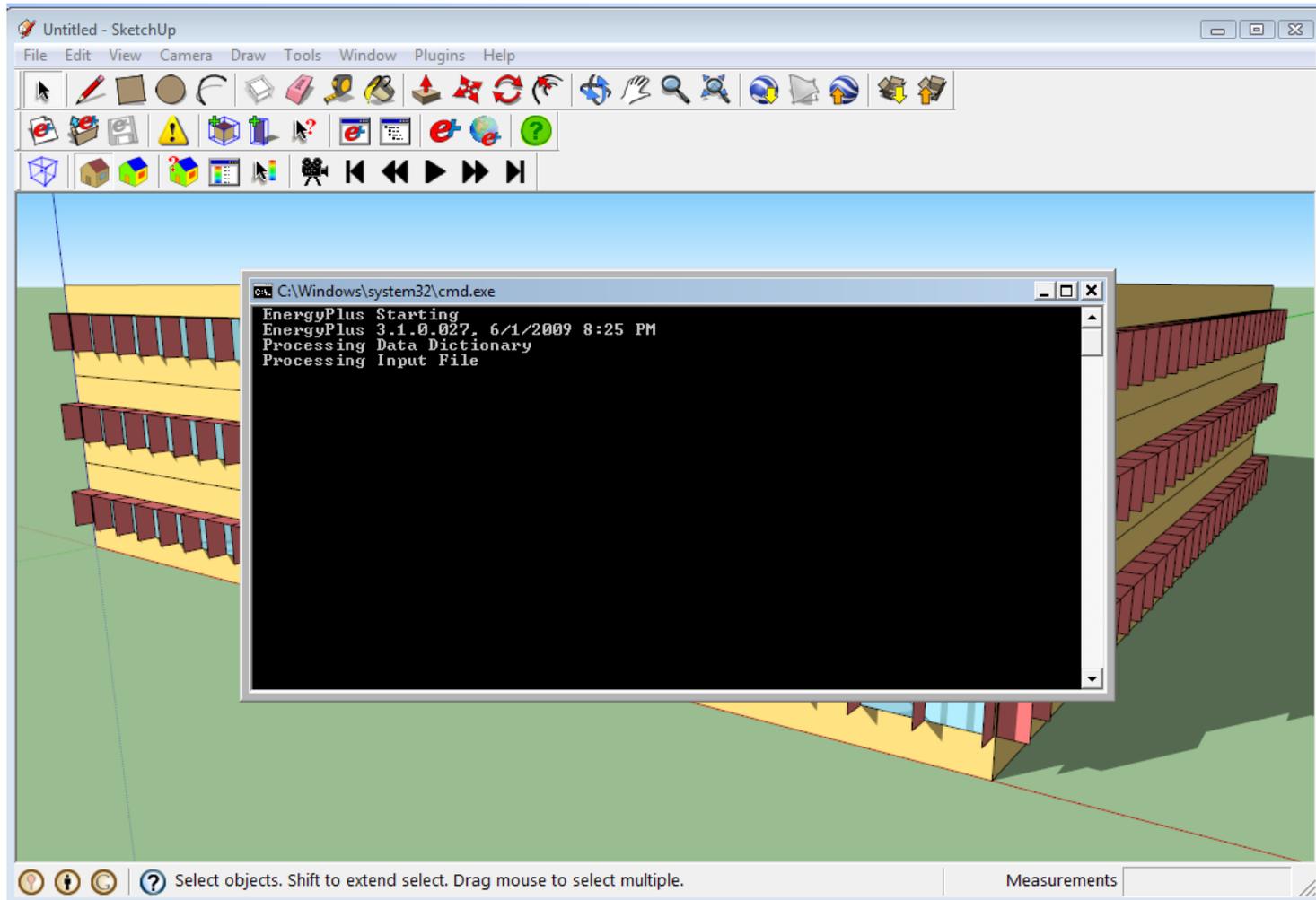
At the bottom of the SketchUp Pro window, a status bar reads: 'Select objects. Shift to extend select. Drag mouse to select multiple.'

# Run Simulation

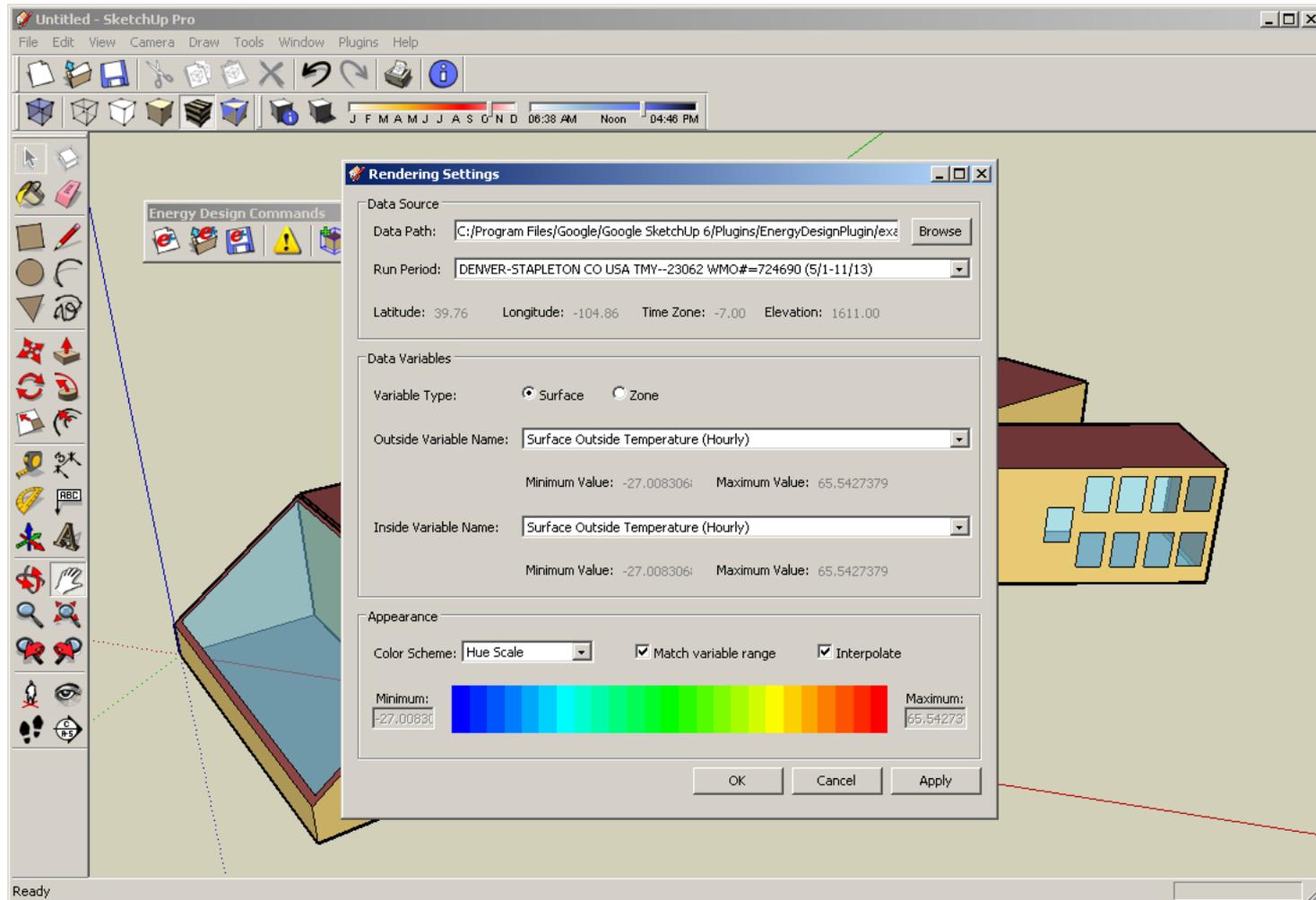


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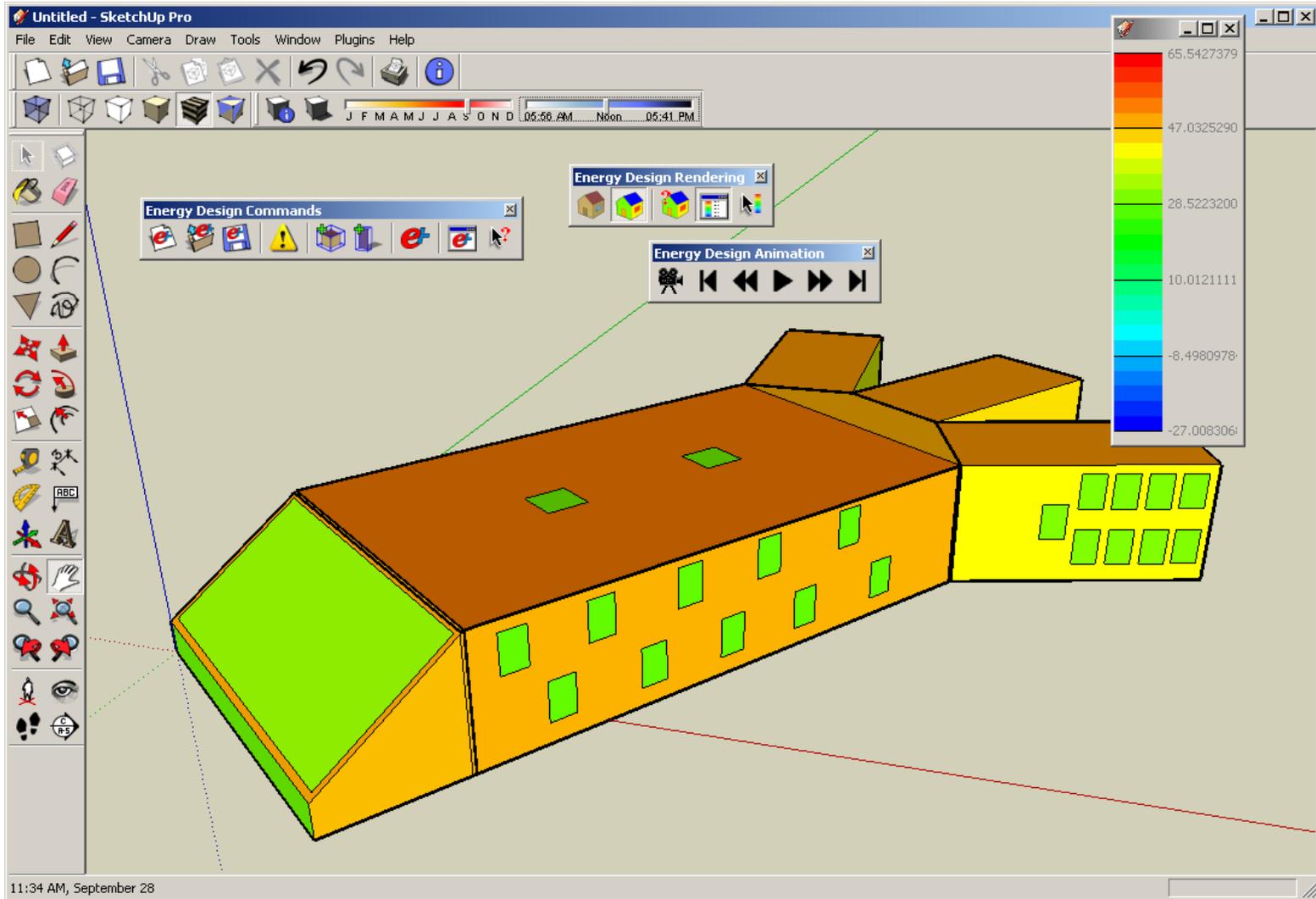
# Run Simulation

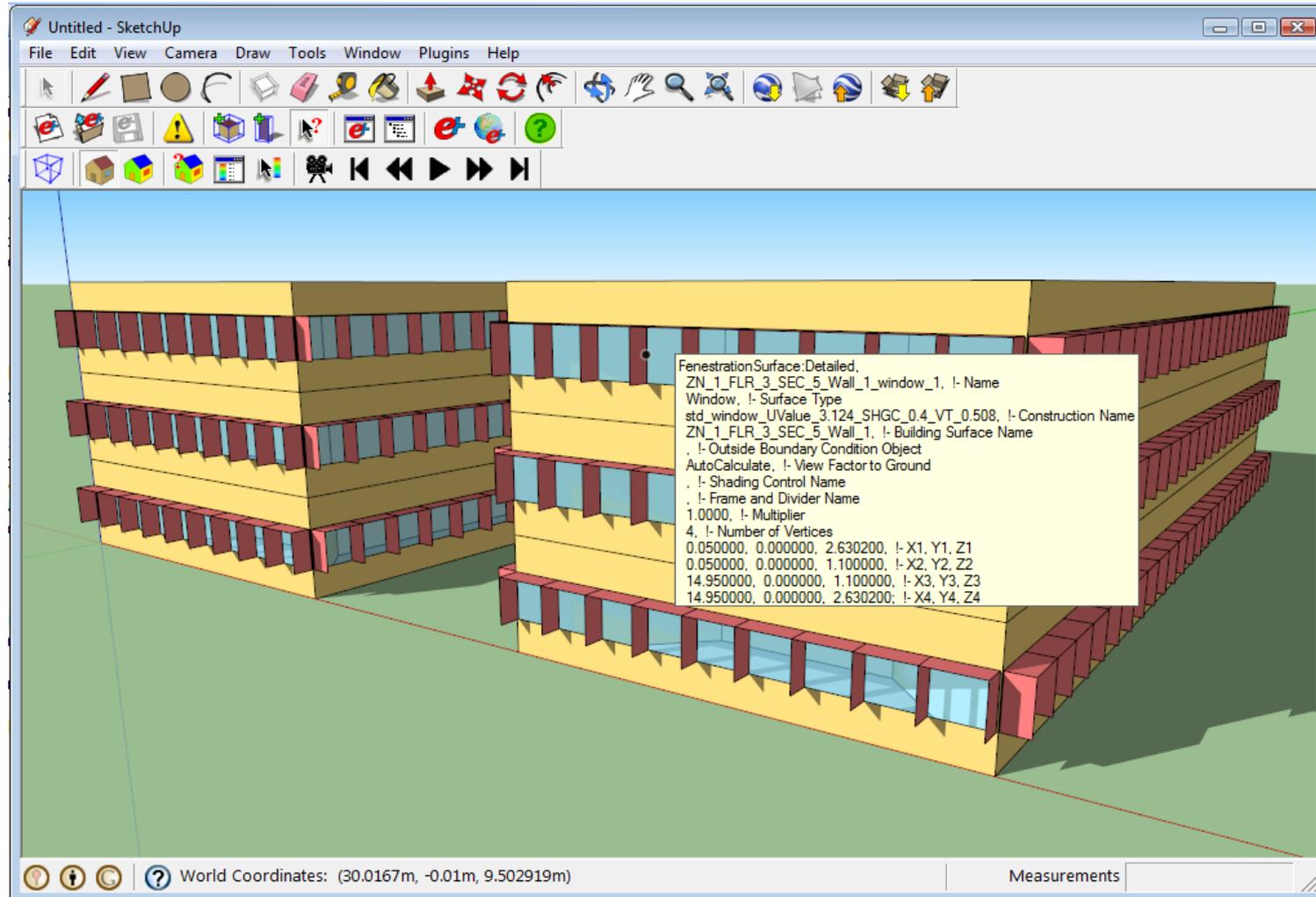


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Introduction to EnergyPlus—Part 1. Copyright 2002–2009 U.S. DOE





Introduction to EnergyPlus—Part 1. Copyright 2002–2009 U.S. DOE

- Developed by NREL
- Open source project
- Current version 1.0.4, October 2009
- Available for free at [www.energyplus.gov](http://www.energyplus.gov)
- Works with free and pro versions of SketchUp
- Available for Windows and Mac

- Conceptual Phase:
  - Quickly create building form and massing
  - **Changes based on simulation feedback**
  - Present design proposals to client
  - Changes based on client feedback
- Design Development:
  - Export from SketchUp to CAD tool
  - Design refinement with CAD

- Not a full-featured interface for EnergyPlus
  - Geometry only
  - Must still be expert user and/or use other tools in conjunction
- Not a translator from SketchUp to EnergyPlus
  - Cannot automatically convert a model
  - Must have the energy model in mind from the beginning

- OpenStudio is still being developed
  - Make sure to “click into the zone” before adding surfaces/subsurfaces
  - Watch for extraneous objects in the IDF file (e.g., walls without zones, windows with no subsurface)
  - Undo may not work as expected
  - Synchronization between IDF and SKP files can fail (**make sure to save your IDF frequently**)
  - Assign other side surfaces

- **EnergyPlus Web site** ([www.energyplus.gov](http://www.energyplus.gov))
  - free program download
  - documentation
  - weather data (more than 2,100 locations worldwide)
  - testing and validation reports
  - developer & commercial distribution licenses
- **User Support Helpdesk**
  - [energyplus.helpserve.com](http://energyplus.helpserve.com)
  - submit questions
    - via Web: [energyplus.helpserve.com](http://energyplus.helpserve.com)
    - via email: [EnergyPlus-Support@gard.com](mailto:EnergyPlus-Support@gard.com)
    - attach input files as needed

- **EnergyPlus Yahoo Technical Group**
  - user-to-user forum
  - join EnergyPlus-Support Yahoo Group at [http://groups.yahoo.com/group/EnergyPlus\\_Support](http://groups.yahoo.com/group/EnergyPlus_Support)
  - subscribe by sending email to [EnergyPlus\\_Support-subscribe@yahoogroups.com](mailto:EnergyPlus_Support-subscribe@yahoogroups.com)
  - post messages by sending email to [EnergyPlus\\_Support@yahoogroups.com](mailto:EnergyPlus_Support@yahoogroups.com)

## **DOE Building Technologies Program**

[buildings.energy.gov](http://buildings.energy.gov)

## **EnergyPlus and OpenStudio**

[energyplus.gov](http://energyplus.gov)

Thanks!

[Drury.Crawley@ee.doe.gov](mailto:Drury.Crawley@ee.doe.gov)